Clinical Update

Naval Postgraduate Dental School
Navy Medicine Professional Development Center
8901 Wisconsin Ave
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Vol. 35, No. 5 2013

New Developments in Rotary Nickel-Titanium Instruments

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Introduction

Historically, carbon steel and stainless steel instruments were used for root canal instrumentation. In 1988, Walia and colleagues introduced nickel-titanium (NiTi) files to endodontics[1]. Since then, many NiTi file systems have been developed. Rotary NiTi instruments have become popular as they can clean and shape root canals with fewer procedural errors and more predictability than stainless steel hand files[2]. The purpose of this clinical update is to 1) review new developments in nickel-titanium metallurgy and their impact on rotary NiTi file systems, and 2) discuss the advantages and disadvantages of using NiTi files in a reciprocating motion versus a continuous rotary motion.

Why is Nickel-Titanium More Flexible?

NiTi alloys are unique in that applied stress (i.e. bending) causes a reversible rearrangement of the nickel and titanium atoms at the molecular level[3]. A new endodontic file is composed of nickel and titanium atoms arranged in a body-centered cubic lattice structure called the *austenite* phase. When this file is placed in a curved canal, the atoms rearrange into a closely-packed hexagonal array and the alloy is transformed into the more flexible *martensite* crystal structure. This molecular transition enables these files to bend easily and around severe curves without permanent deformation. When the stress is removed, the alloy reverts back to its initial austenite form. This stress-induced martensitic transformation is a unique property of NiTi alloys and makes this material one of the few alloys suitable for use in rotary endodontic instruments[3,4].

Advances in Nickel-Titanium Metallurgy

In the last several years, new forms of NiTi have been created by heating the alloy during the manufacturing process, resulting in a combination of heat-treatment and hardening[4]:

1. M-wire NiTi was developed by Dentsply Tulsa Dental Specialties (Tulsa, OK, USA) using a proprietary thermal cycling process. The manufacturer claims this material has greater flexibility and an increased resistance to cyclic fatigue when compared to traditional NiTi alloys. Three file systems fabricated from M-wire NiTi are the ProFile Vortex, GT Series X and PROTAPER NEXT files.

2. R-phase NiTi is a rhombohedral crystal structure that can be formed during the martensite-austenite or austenite-martensite transition. SybronEndo (Orange, CA, USA) developed files that contain this crystal structure through a patented process of heating the NiTi, twisting the intermediate alloy, then further heat-treating the material to produce the final product. Twisted Files (TF) and K3XF files are based on R-phase NiTi technology, and the manufacturer claims the files have reduced stiffness and more fracture resistance compared to standard NiTi files.

3. Controlled-Memory (CM) NiTi refers to alloys where manufacturers use proprietary processing to reduce the shape-memory normally characteristic of NiTi files. This allows the instruments to be pre-curved prior to placing them into the root canal. Sterilization of the files will return them to their original shape. CM NiTi file systems available include Hyflex CM (Coltene Whaledent, Cuyahoga Falls, OH, USA), Typhoon CM (Clinician's Choice Dental Products, New Milford, CT, USA) and ProFile Vortex Blue (Dentsply Tulsa Dental Specialties). Manufacturers claim these files have superior cyclic fatigue resistance and increased torque strength over traditional NiTi files.

New Files with Improved Physical Properties

Research has demonstrated that all three new forms of NiTi contain the martensite crystal structure at room temperature without applied stress[4,5]. Since the martensite phase is more elastic and ductile than the stronger, harder austenite phase, this compositional change gives these new file systems physical properties better suited for preparing root canals than previous rotary NiTi files.

Numerous research studies have supported these claims by file manufacturers. To assess cyclic fatigue resistance, files are rotated in simulated root canals until fracture; to assess flexibility, they are clamped near the tip and the force required to produce a 45° bend is measured. These tests have been conducted by different research groups using GT Series X, ProFile Vortex, CM-wire, HyFlex CM, and ProFile Vortex Blue files. The results have indicated that these new NiTi files have significantly greater cyclic fatigue resistance and flexibility than their counterparts made from traditional NiTi[6-10]. Other studies have demonstrated that the centering ability is improved and transportation is reduced when using ProFile Vortex and generic M-wire samples[11]. Since heat-treatment affects the physical properties of NiTi alloys, autoclaving could modify their physical properties; however, up to seven sterilization cycles have not significantly impacted the flexibility or fracture resistance of M-wire (ProFile Vortex), R-phase (TF) or CM-wire NiTi instruments[12].

Reciprocating Files

Most NiTi files are rotated continuously during instrumentation. While this effectively prepares the canal, it can lead to cyclic fatigue and instrument fracture. To decrease this risk, files have been designed for use in a reciprocating motion, turning a specific distance clockwise, then rotating counter-clockwise. The clockwise and counterclockwise rotations are usually not equivalent, so the file advances through a partial clockwise rotation with each reciprocation cycle. Manufacturers have also developed handpiece motors with settings specific to their file systems to use with these reciprocating files.

Research on Reciprocating Files

Numerous articles have been published evaluating the physical properties of reciprocating files. Most studies compare file systems designed for reciprocal motion (WaveOne, Dentsply Maillefer, Tulsa, OK, USA; Reciproc, Munich, Germany), or compare one of these systems to traditional NiTi files used in a reciprocating motion. Using

the same methodology described previously for determining cyclic fatigue resistance and flexibility, files used in a reciprocating motion demonstrated significantly greater cyclic fatigue resistance relative to files used in continuous rotation[13-15]. In theory, this is desirable and should decrease the risk of an instrument fracturing during instrumentation.

Literature on the use of reciprocating files has not demonstrated consensus. Berutti and colleagues suggested that the WaveOne reciprocating file system maintained canal curvatures better than ProTaper files used in continuous rotation[16], while Bürklein and colleagues suggested no significant difference using the same file systems[17]. It is important to note that Berutti's group used endodontic training blocks (plastic) while Bürklein's group used extracted human teeth. Thus, the results from the latter study may better represent clinical conditions. Stern and colleagues also noted no significant difference in canal position and shaping when using files in continuous rotation or reciprocation.[18] Another study by Bürklein's group suggested that files used in reciprocation were faster than those used in continuous motion,[19] while Franco and colleagues suggested they could be more time consuming[20]. Other research has indicated that reciprocating files decrease working length (by straightening the canal) and extrude more debris apically than files used in continuous rotation[19,21].

Conclusions

Recent advancements in the manufacturing process of NiTi alloys have allowed for the development of rotary endodontic file systems that are more flexible, less likely to fracture and more capable of maintaining the original canal position than their predecessors. These instruments have great clinical potential and can be used in lieu of older file systems, keeping in mind that it is important to always use files in the sequence and at the torque and RPM settings recommended by the manufacturer.

While reciprocating files have the potential to advance endodontic instrumentation, research to date has not indicated they are superior to files used in continuous rotation. Consequently, they cannot be recommended over traditional file systems at this time.

References

1. Walia HM, Brantley WA, Gerstein H. An initial investigation of the bending and torsional properties of Nitinol root canal files. J Endod 1988 Jul; 14(7): 346-51.
2. Short JA, Morgan LA, Baumgartner JC. A comparison of canal centering ability of four instrumentation techniques. J Endod 1997 Aug; 23(8): 503-7.
3. Thompson SA. An overview of nickel titanium alloys used in dentistry. Int Endod J 2000 Apr; 33(4): 297-310.
4. Shen Y, Zhou HM, Zheng YF, Peng B, Haapasalo M. Current challenges and concepts of the thermomechanical treatment of nickel-titanium instruments. J Endod 2013 Feb; 39(2): 163-72.
5. Alapati SB, Brantley WA, Iijima M, Clark WA, Kovarik L, Buie C, Liu J, Ben Johnson W. Metallurgical characterization of a new nickel-titanium wire for rotary endodontic instruments. J Endod 2009 Nov; 35(11): 1589-93.
6. Al-Hadlaq SM, Aljarbou FA, AlThumairy RI. Evaluation of cyclic fatigue of M-wire nickel-titanium rotary instruments. J Endod 2010 Feb; 36(2): 305-7.
7. Gao Y, Shotton V, Wilkinson K, Phillips G, Johnson WB. Effects of raw material and rotational speed on the cyclic fatigue of ProFile Vortex rotary instruments. J Endod 2010 Jul; 36(7): 1205-9.
8. Gao Y, Gutmann JL, Wilkinson K, Maxwell R, Ammon D. Evaluation of the impact of raw materials on the fatigue and mechanical properties of ProFile Vortex rotary instruments. J Endod 2012 Mar; 38(3): 398-401.
9. Ninan E, Berzins DW. Torsion and bending properties of shape memory and superelastic nickel-titanium rotary instruments. J Endod 2013 Jan; 39(1): 101-4.
10. Ye J, Gao Y. Metallurgical characterization of M-wire nickel-titanium shape memory alloy used for endodontic rotary instruments during low-cycle fatigue. J Endod 2012 Jan; 38(1): 105-7.
11. Yamamura B, Cox TC, Heddaya B, Flake NM, Johnson JD, Paranjpe A. Comparing canal transportation and centering ability of EndoSequence and Vortex rotary files by using micro-computed tomography. J Endod 2012 Aug; 38(8): 1121-5.
12. Casper RB, Roberts HW, Roberts MD, Himel VT, Bergeron BE. Comparison of autoclaving effects on torsional deformation and fracture resistance of three innovative endodontic file systems. J Endod 2011 Nov; 37(3): 1572-5.
13. Kim HC, Kwak SW, Cheung GS, Ko DH, Chung SM, Lee W. Cyclic fatigue and torsional resistance of two new nickel-titanium instruments used in reciprocation motion: Reciproc versus WaveOne. J Endod 2012 Apr; 38(4): 541-4.
14. Gambarini G, Gergi R, Naaman A, Osta N, Al Sudani D. Cyclic fatigue analysis of twisted file rotary NiTi instruments used in reciprocating motion. Int Endod J 2012 Sept; 45(9): 802-6.
15. Castelló-Escrivá R, Alegre-Domingo T, Faus-Matoses V, Román-Richon S, Faus-Llácer VJ. *In vitro* comparison of cyclic fatigue resistance of ProTaper, WaveOne, and Twisted Files. J Endod 2012 Nov; 38(11): 1521-4.
16. Berutti E, Chiandussi G, Paolino DS, Scotti N, Cantatore G, Castellucci A, Pasqualini D. Canal shaping with WaveOne primary reciprocating files and ProTaper system: a comparative study. J Endod 2012 Apr; 38(4): 505-9.
17. Bürklein S, Hinschitza K, Dammaschke T, Schäfer E. Shaping ability and cleaning effectiveness of two single-file systems in severely curved root canals of extracted teeth: Reciproc and WaveOne versus Mtwo and ProTaper. Int Endod J 2012 May; 45(5): 449-61.
18. Stern S, Patel S, Foschi F, Sheriff M, Mannocci F. Changes in centering and shaping ability using three nickel-titanium instrumentation techniques analysed by micro-computed tomography (μCT). Int Endod J 2012 Jun; 45(6): 514-23.
19. Bürklein S, Schäfer E. Apically extruded debris with reciprocating single-file and full-sequence rotary instrumentation systems. J Endod 2012 Jun; 38(6): 850-2.
20. Franco V, Fabiani C, Taschieri S, Malentacca A, Bortolin M, Del Fabbro M. Investigation on the shaping ability of nickel-titanium files when used with a reciprocating motion. J Endod 2011 Oct; 37(10): 1398-401.
21. Berutti E, Chiandussi G, Paolino DS, Scotti N, Cantatore G, Castellucci A, Pasqualini D. Effect of canal length and curvature on working length alteration with WaveOne reciprocating files. J Endod 2011 Dec; 37(12): 1687-90.

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